

17. Faults and Seismicity

17.1 Introduction

This chapter describes the faults and seismicity setting for the Extended, Secondary, and Primary study areas. Descriptions and maps of these three study areas are provided in Chapter 1 Introduction.

The regulatory setting for faults and seismicity is discussed briefly in this chapter, and is presented in greater detail in Chapter 4 Environmental Compliance and Permit Summary.

This chapter focuses primarily on the Primary Study Area. Potential impacts in the Secondary and Extended study areas were evaluated and discussed qualitatively. Potential local and regional impacts from constructing, operating, and maintaining the alternatives were described and compared to applicable significance thresholds. Mitigation measures are provided for identified significant or potentially significant impacts, where appropriate.

17.2 Environmental Setting/Affected Environment

17.2.1 Introduction

17.2.1.1 Fault Activity Classification

Faults are classified as active, potentially active, or inactive by the California Geological Survey (CGS), based on the age of most recent activity, as defined below:

- Historic faults have experienced surface rupture during historic time (approximately the last 200 years) and are associated with either a recorded earthquake with surface rupture, measurable surface displacement along a fault in the absence of notable earthquakes (aseismic creep), or displaced fault survey lines.
- Holocene age faults have had surface displacement within the past 11,000 years, as demonstrated by young geomorphic evidence, offset young deposits, or radiometrically dated material.
- Late Quaternary age faults show evidence of surface rupture within approximately the last 700,000 years, as demonstrated using the same geomorphic evidence as for Holocene faults.
- Quaternary age faults show evidence of surface rupture younger than approximately 1.6 million years ago, including faults that displace undifferentiated Plio-Pleistocene age deposits.
- Pre-Quaternary age faults show no evidence of movement within the Quaternary (approximately the past 1.6 million years) or lack evidence of displacement of younger deposits. Also included in this category are known faults for which detailed studies have not determined fault activity, and those faults identified only in preliminary mapping (Jennings, 1999).

The classification of “active” is applied to historic and Holocene age faults, “potentially active” is applied to Quaternary and late Quaternary age faults, and “inactive” is applied to pre-Quaternary age faults. These classifications were developed by the CGS and were adopted by the Alquist Priolo Act (1972) to help delineate Special Studies Zones where detailed geologic investigations are required prior to development. These classifications are not meant to imply that inactive fault traces will not rupture, only that they have not been shown to have ruptured for some time and the probability of fault rupture is low. The Alquist

Priolo Special Studies Zones do not address subsurface or “blind” faults, which can cause significant earthquake damage without surface rupture.

The California Department of Water Resources, Division of Safety of Dams (DSOD) has published “Fault Activity Guidelines” (Fraser, 2001) that uses a more stringent criteria on fault activity classification than CGS. Its publication defines an active fault as having ruptured within the last 35,000 years. A conditionally active fault is defined as having ruptured in the Quaternary, but its displacement history during the last 35,000 years is unknown. Fault inactivity is demonstrated by a confidently located fault trace that is consistently overlain by unbroken geologic materials older than 35,000 years. Faults that have no indication of Quaternary activity are presumed to be inactive, except in regions of sparse Quaternary cover.

Table 17-1 compares the difference in fault activity classifications between CGS and DSOD. For this chapter, the more stringent fault activity classification set forth by DSOD is used.

Table 17-1
Comparison of Fault Activity Classification between the California Geological Survey and Division of Safety of Dams

Period	Epoch	Years Before Present	Fault Activity Classification	
			CGS	DSOD
Quaternary	Holocene	0 to 12,000 years	Active (Up to 11,00 years)	Active (Up to 35,000 years)
	Pleistocene	12,000 to 1.6 million years	Potentially active (Up to 1.6 million years)	Conditionally active (Up to 1.6 million years)
Pre-Quaternary			Inactive (Greater than 1.6 million years)	Inactive (Greater than 1.6 million years)

Notes:

CGS = California Geological Survey

DSOD = Division of Safety of Dams

17.2.1.2 Earthquake Magnitude and Intensity Measurement

Earthquake magnitude is a quantitative measure of the strength of an earthquake or the strain energy released by it, as determined by the seismographic or geologic observations. It does not vary with distance or the underlying earth material. This differs from earthquake intensity, which is a qualitative measure of the effects a given earthquake has on people, structures, loose objects, and the ground at a specific location. Intensity generally increases with increasing magnitude and in areas underlain by unconsolidated materials, and decreases with distance from the hypocenter (source of seismic energy) (CGS, 2002).

Several magnitude scales have been developed by seismologists. The original is the Richter magnitude, which measures the maximum trace amplitude registered on a seismogram. With appropriate distance corrections for the appropriate amplitude, the magnitude value is constant and is an effective means of earthquake size classification.

The most commonly used scale is the moment magnitude scale. Moment magnitude is related to the physical size of fault rupture and the movement or displacement across the fault, and as such, is a more uniform measure of the strength of an earthquake. Another measure of earthquake size is seismic

moment. The seismic moment determines the energy that can be radiated by an earthquake. The moment magnitude of an earthquake is defined relative to the seismic moment for that event.

An earthquake's magnitude is expressed in whole numbers and decimals (e.g., M6.8).

Earthquake intensity in a given location is typically measured using the Modified Mercalli intensity scale with values ranging from I to XII. The most commonly used adaptation covers the range of intensities from "I" (not felt except by very few, favorably situated), to "XII" (total damage, lines of sight disturbed, and objects thrown into the air).

Although an earthquake has only one magnitude, it can have many intensities that typically decrease with distance from the epicenter. Table 17-2 presents an approximate relationship between magnitude and maximum expected intensity close to the epicenter.

Table 17-2
Comparison of Richter Magnitude and Modified Mercalli Intensity

Richter Magnitude	Expected Modified Mercalli Maximum Intensity (at epicenter)	
	Intensity	Observations and Effects
2	I – II	Usually detected only by instruments
3	III	Felt indoors
4	IV – V	Felt by most people; slight damage
5	VI – VII	Felt by all; many frightened and run outdoors; damage minor to moderate
6	VII – VIII	Everybody runs outdoors; damage moderate to major
7	IX – X	Major damage
8+	X – XII	Total and major damage

Source: Richter, 1958.

17.2.2 Extended Study Area

California straddles the juncture of two great crustal plates: the Pacific Plate and the North American Plate (CGS, 2003a). The cities of Monterey, Santa Barbara, Los Angeles, and San Diego are located on the Pacific Plate, which is constantly moving northwestward past the North American Plate. The North American Plate includes the remainder of California east of the San Andreas Fault¹. The San Andreas Fault extends from the Gulf of California northwestward to Mendocino County and ends at the "Triple Junction" offshore of Cape Mendocino. The Triple Junction is where the American Plate, Pacific Plate, and the off-shore Gorda Plate meet. The relative rate of movement is approximately two inches (50 millimeters [mm]) per year. In California, approximately 40 mm per year of the slip occurs on the faults of the San Andreas system, and about 10 mm per year of slip occurs on faults in the Mojave Desert and Basin and Range area, east of the Sierra Nevada (a system known as the eastern California shear zone).

The constant motion of the crustal plates causes stress in the brittle upper crust of the earth. These tectonic stresses build up as the rocks are gradually deformed. This rock deformation, or strain, is stored in the rocks as elastic strain energy. When the strength of the rock is exceeded, rupture occurs along a

¹Fractures in the earth's crust along which the rocks on one side have shifted relative to those on the other side are called faults. The total amount of displacement along a fault may be a few inches or many miles if it has accumulated over millions of years. Faults are more likely to have future earthquakes if they have had more recent earthquakes along them, have had greater total displacement, and are aligned so that movement can relieve the accumulating tectonic stresses.

fault. The rocks on opposite sides of the fault slide past each other as the rocks spring back to a relaxed position. The strain energy is released partly as heat and partly as seismic waves. These seismic waves produce the ground shaking of an earthquake.

There are thousands of recognized faults in California, hundreds of which have been given formal names, but only a very small number of these pose significant hazards. These faults are shown relative to the CVP and SWP service areas within the Extended Study Area (Figure 17-1). The motion between the Pacific and North American plates occurs primarily on the faults of the San Andreas Fault system and the eastern California shear zone. Other faults have much lower rates of movement, and correspondingly longer times between significant earthquakes.

Ground shaking from large earthquakes is responsible for most of the damage caused by earthquakes. Damage to structures is related to the type and quality of construction, and foundation materials. Building codes have been periodically revised to account for our current understanding of how earthquake shaking can damage buildings. Other earthquake hazards, including the surface rupture of a fault, and liquefaction and landslides that can be caused by the shaking, are significant hazards.

Earthquakes are detected every day in California by sensitive seismographs that record the very small vibrations of the earth. Each year, 100 to 150 earthquakes occur in the state that are big enough to be felt, but few of these cause damage. Earthquakes large enough to cause moderate damage to structures in the vicinity of the epicenter – those of M5 or larger – occur three or four times a year (CGS, 2003a).

On an average of once every two or three years, a moderate earthquake (M6 to 6.9) strikes somewhere in the state. An earthquake of this size, such as the Northridge (southern California) Earthquake of January 17, 1994 (M6.7) or the Coalinga (central California) Earthquake of May 2, 1983 (M6.5) is capable of causing major damage if the epicenter is near a densely populated area (CGS, 2003a).

Major earthquakes (M7 to 7.9) occur in California approximately every 10 years. Two recent major earthquakes, the Landers (San Bernardino County) Earthquake of June 28, 1992 (M7.3) and the Hector Mine (San Bernardino County) Earthquake of October 16, 1999 (M7.1) caused extensive surface fault rupture, but relatively little damage because they occurred in lightly populated areas of the Mojave Desert. Earthquakes of similar size, such as the M6.9 Loma Prieta (Santa Cruz County) Earthquake of October 17, 1989, cause extensive damage over large areas when they occur in densely populated regions. The two largest earthquakes in California, the Fort Tejon (Kern County) Earthquake of 1857 and the famous San Francisco Earthquake of 1906, were similar in magnitude (M7.9 and M7.8, respectively) and resulted from movement along the San Andreas Fault. Earthquakes of this size (M7.7 to 7.9) can cause more extensive damage over a larger area than the M7.1 to 7.4 earthquakes that have stricken California in recent decades (CGS, 2003a).

Great earthquakes (M greater than 8) have not occurred in California in historic time, but one earthquake in January 1700 may have been this large. Based on Native American oral histories, tree-ring studies, geological studies that show the uplift or subsidence of large areas of coastal land, and records of a tsunami that struck Japan and cannot be correlated with an earthquake anywhere else around the Pacific, a great (M9) earthquake occurred January 26, 1700 on the Cascadia Subduction Zone extending north from Cape Mendocino to British Columbia. An earthquake of this size is similar to the one that struck Alaska in 1964, and is capable of extensive damage over a very broad region (CGS, 2003a).

B.F. Sisk Dam, which impounds San Luis Reservoir, is near two seismic faults. It is 28 miles from the San Andreas Fault, and 23 miles from the Calaveras-Hayward Fault.

Reservoir-induced seismicity is a phenomenon where the weight of large deep reservoirs and the increased pore pressures trigger small localized earthquakes. Within the Extended Study Area, San Luis Reservoir has been suspected of creating reservoir-induced seismicity (William Lettis & Associates, Inc., 2002; Probe International, 2008).

During a period of rapid inflow in January and February 1969, a four-fold increase in seismic activity was recorded in the vicinity of San Luis Reservoir, followed by an additional 38 events during the remainder of the year. Subsequent to this, seismicity returned to background levels (Anderson et al., 1982). In 1974, 11 earthquakes occurred at the southern end of the reservoir during a period when there were minimal changes in water level. This subsequent series of events brought into question whether the 1969 activity was related to reservoir-induced seismicity (Wong and Strangberg, 1996).

17.2.3 Secondary Study Area

Faults and seismicity are a regional phenomenon. Movement on faults within the Secondary Study Area could have potential effects on Project features within the Primary Study Area. Although this discussion addresses faults and seismicity within the Secondary Study Area, their location relative to the Primary Study Area has been included.

Table 17-3 lists the locations of regionally active faults and potentially active faults significant to the Secondary Study Area due to proximity, activity status, date of most recent motion, and maximum moment magnitude (Mmax)². Figure 17-2 shows the active and potentially active faults within the Secondary Study Area that could affect the operation of the proposed Project.

Table 17-3
Regional Active and Potentially Active Faults in the Secondary Study Area

Fault	Fault Type	Recency of Movement	Fault Classification	Maximum Moment Magnitude (Mmax)
San Andreas	Strike Slip	Holocene	Active	~8.0
Maacama Fault	Strike Slip	Holocene	Active	6.5
Bartlett Springs	Strike Slip	Holocene	Active	6.6
Coast Range	Normal	Late Pliocene	Not Active	Not characterized
Green Valley	Thrust	Pre-Late Quaternary	Not Active	Not characterized
Stony Creek	Thrust	Pre-Quaternary	Not Active	Not characterized
Great Valley	Blind Thrust	Holocene	Assumed to be Active	6.8
Corning	Blind Reverse	Late Pleistocene	Active	Not characterized
Cleveland Hills	Normal	Holocene	Active	5.7
Cascadia Subduction Zone	Megathrust	Holocene	Active	9

Source: William Lettis & Associates, Inc., 2002.

The right-lateral San Andreas Fault system forms the boundary between the North American and Pacific plates. The San Andreas Fault trends southeast from Cape Mendocino to the Gulf of California. Between Cape Mendocino and San Francisco, some portions of the fault lie off the coast of California. The San Andreas Fault has experienced significant activity during historic time, most recently during the 1989 Loma Prieta Earthquake (M6.9), which resulted in widespread damage throughout the Bay Area.

² The Mmax is the strongest earthquake that is likely to be generated along a fault. It is based on empirical relationships of surface rupture length, rupture area, and fault type, which are all related to the physical size of fault rupture and displacement across a fault.

Prior to that, the 1906 San Francisco Earthquake (estimated at M7.9) caused approximately 290 miles of surface fault rupture from Tomales Bay southward.

East of the San Andreas Fault, several strike-slip faults occur in northwest trending valleys, including the Maacama Fault and the Bartlett Springs Fault. Both faults have been active in Holocene time and are capable of producing seismic events up to M6.6. The CGS has published several Alquist-Priolo maps along both of these faults.

Further east, several inactive faults (Coast Range, Green Valley, and Stony Creek) occur at or near the contact between the Franciscan Formation and the Great Valley Sequence. Movement along these fault planes is generally attributed to eastward compression of the Coast Range and slippage along bedding planes. These three faults are considered not active.

The Great Valley Fault is a low-angle blind thrust fault located along the west side of the Sacramento and San Joaquin valleys. The fault plane is deepest to the west in rocks of the Coast Range Geomorphic Province and trends upward into sedimentary rocks of the Great Valley Geomorphic Province. It is a main component of the Coast Ranges-Sierran Block Boundary Zone, a broad compressional boundary between the Pacific Plate and the Sierra Nevada Microplate of North America (William Lettis & Associates, Inc., 2002). In its closest proximity to the Primary Study Area, it is approximately four to seven miles below the surface. Historically, seismic activity has occurred along the Great Valley Fault in the Sacramento Valley, notably the 1889 Antioch Earthquake (M6) and the 1892 Winters earthquakes (M6+). In addition, a swarm of small earthquakes (M3.6 to M4.0) occurred in the region of Maxwell and Williams in late 1943 that are believed to have originated along the Great Valley Fault. The segment of the Great Valley Fault nearest to Primary Study Area is assumed to be active.

The Corning Fault is a blind reverse fault located west of the Sacramento River and extending from Red Bluff southward into Glenn County. The fault trace is not visible on the surface. Based on evidence of uplifting and folding of the Modesto Formation (late Pleistocene) across the trace of the fault, the Corning fault is considered active.

The Cascadia Subduction Zone is the boundary between the subducting Pacific Plate and the North American Plate. Its closest occurrence to the Primary Study Area is approximately 150 miles west-northwest offshore of northern California, north of Cape Mendocino. The zone extends north offshore of Oregon, Washington, and southern Canada. Geological investigations (Atwater et al., 1995; Nelson et al., 1995), geophysical modeling (Fluck et al., 1997; Hyndman and Wang, 1995), and historical tsunami records from Japan (Satake et al., 1996) provide the basis for the current scientific consensus that the Cascadia Subduction Zone has the potential to generate mega-earthquakes that may rupture the entire 1,500-mile length of the plate boundary, with seismic events exceeding M9. The most recent great earthquake is estimated to have occurred approximately 300 years ago in 1700, based on tree ring evidence and Japanese tsunami records. Paleoseismic data indicate that earthquakes of this size may occur every 500 to 600 years. Historically, the 1992 Cape Mendocino earthquake (M7 to M7.2) is the most recent earthquake to occur on the Cascadia Subduction Zone.

The Cleveland Hills Fault is a normal fault located south of Lake Oroville. In 1975, several earthquakes occurred along the fault; the greatest event was M5.7. Surface rupturing along the fault line occurred for several miles. The fault is considered active. One Alquist-Priolo Act map was published mapping areas of surface rupture along the fault line.

Figure 17-3 shows the locations of seismic events within the Secondary Study Area. The majority of the historical seismic activity is associated with movement along the Bartlett Springs and Maacama faults west of the Primary Study Area. The concentration of seismic activity to the northwest is associated with the “Triple Junction”. Earthquake hazards are greater there because that region is part of the Cascadia Subduction Zone, where plate collisions increase the potential for huge earthquakes. A cluster of minor to moderate seismic events in the Oroville area is associated with the Cleveland Hill Fault. Additional minor seismic activity occurs throughout the Secondary Study Area, and is generally attributed to compressional forces between the Coast Range Geomorphic Province and the Great Valley Geomorphic Province. These minor seismic events occur at moderate depth with no surface expression exhibited (William Lettis & Associates, Inc., 2002).

The CGS has produced an Earthquake Shaking Potential for California Map (CGS, 2008a). The map indicates that seismic shaking potential in the Secondary Study Area ranges from low to high, with the highest potentials existing along the San Andreas Fault and other faults in the Coast Range and southern California.

Liquefaction is the loss of soil strength due to seismic forces generating various types of ground failure. The potential for liquefaction must account for soil types and density, the groundwater table, and the duration and intensity of ground shaking. The USGS has produced numerous maps of areas within the Secondary Study Area showing liquefaction potential (USGS, 1996a). Many areas, such as artificial fill adjacent to the San Francisco Bay, have a high liquefaction potential.

The CGS has produced numerous maps showing landslide features and delineating potential slope-stability problem areas (CGS, 2011a). Many areas within the Secondary Study Area have high landslide susceptibility (CGS, 2011b).

Within the Secondary Study Area, Shasta Lake and Lake Oroville have been suspected of creating reservoir-induced seismicity (William Lettis & Associates, Inc., 2002; Probe International, 2008).

17.2.4 Primary Study Area

17.2.4.1 Methodology

William Lettis & Associates, Inc. completed a Phase II Fault and Seismic Hazards Investigation for the NODOS Integrated Storage Investigations in 2002. The report focused on the area around the proposed Sites Reservoir, particularly the proposed damsites, and is the primary source of information presented for the Primary Study Area in this chapter.

17.2.4.2 Fault Rupture Potential

No faults of Holocene age (i.e., active faults) are known to occur within the Primary Study Area. No Alquist-Priolo Act maps have been published for areas within the Primary Study Area.

The Phase II Fault and Seismic Hazards Investigation for the NODOS Integrated Storage Investigations (William Lettis & Associates, Inc., 2002) identified several inactive faults in proximity to the proposed Sites Reservoir and the Sites and Golden Gate damsites (Table 17-4). Two major sets of surface faults were recognized:

1. Northeast-striking high-angle faults that obliquely cut across the north-striking bedrock units, and consistently displace stratigraphic contacts in a right-lateral sense. Specific examples of these

structures include the informally named GG-1, GG-2, GG-3 and S-2 faults, all of which pass directly through the proposed Sites and Golden Gate damsites or are located near them (Figure 17-4).

2. North-striking faults that are generally parallel to bedding (Figure 17-4). The most laterally continuous example of these structures is the Salt Lake Thrust Fault, which is parallel to, and east of, the axis of the Sites anticline³. The Salt Lake Thrust Fault is approximately 0.9 mile west of the proposed Golden Gate damsites, and the southern end of the fault is approximately 1.7 miles northwest of the proposed Sites damsites. The trace of the fault passes through the site of proposed saddle dam SSD-2.

The northeast-striking GG-1, GG-2, GG-3, and S-2 faults are tear faults accommodating compression of the overlying formations above the plane of the Great Valley Thrust Fault. Movement along these faults probably occurred as a co-seismic event of moderate to large magnitude earthquakes on the underlying Great Valley Thrust Fault and probably do not act as independent seismic sources (William Lettis & Associates, Inc., 2002).

The Salt Lake Thrust Fault is an offshoot of the Great Valley Thrust Fault trending upward. Trench investigations across the trace of the Salt Lake Thrust Fault indicated that at least one, and probably three or more, surface ruptures have occurred in the past 30,000 to 70,000 years. If rupture events have a regular recurrence, then the trench evidence suggests that at least one surface rupturing event probably has occurred in the past 35,000 years (William Lettis & Associates, Inc., 2002).

The Phase II Fault and Seismic Hazards Investigation for the NODOS Integrated Storage Investigations (William Lettis & Associates, Inc., 2002) concluded that a three- to eight-inch fault slippage could occur along the northeast-striking GG-1, GG-2, GG-3, and S-2 faults that are located beneath the Project damsites or are in proximity to them. This slippage is assumed to be related to movement at depth along the Great Valley Thrust Fault.

Table 17-4
Faults in Proximity to the Proposed Sites Reservoir and Sites and Golden Gate Damsites

Fault	Fault Length	Sense of Displacement	Fault Separation (Horizontal)	Fault Separation (Vertical)	Fault Width	Nearest Distance to Golden Gate Damsite	Nearest Distance to Sites Damsite	Time of Last Movement*
GG-1	1.1 miles	Right-lateral	246 ± 82 feet	Unknown	2 feet	< 0.5 mile	3.1 miles	Holocene deposits unfaulted
GG-2	3.7 miles	Right-lateral	1,312 ±196/-98 feet	Unknown	2 feet	< 0.5 mile	1.7 miles	Holocene deposits unfaulted
GG-3	3.0 miles	Right-lateral	1,574 ± 65 feet	Unknown	2 feet	< 0.5 mile	0.4 mile	Early Holocene deposits unfaulted
S-2	2.4 miles	Right-lateral	558 ±164/-180 feet	None	3 feet	2.2 miles	< 0.5 mile	Early Holocene deposits unfaulted
S-3	Unknown	Thrust (east side up)	Unknown	Unknown	6 feet	600 feet	0.9 mile	Older than, and offset by, Faults S-2, GG-3
Salt Lake Thrust Fault	> 7 miles	Thrust (east side up)	Unknown	> 10 feet	2 feet	1.7 miles	0.9 mile	Pleistocene gravels offset

*Youngest faulted or oldest deposits that cross the fault are given.

Source: William Lettis & Associates, 2002.

³ An anticline is a fold with strata sloping downward on both sides from a common crest.

17.2.4.3 Seismic Ground Shaking

On the basis of a probabilistic seismic hazard map that depicts the peak horizontal ground acceleration values exceeded at a 10 percent probability in 50 years (CGS, 2003b), the probabilistic peak horizontal ground acceleration values within the Primary Study Area range from 0.1g to 0.3g (where g equals the acceleration speed of gravity). These values indicate that the ground-shaking hazard in the Primary Study Area is moderately low.

Ground shaking intensity is largely a function of distance from the earthquake epicenter and underlying geology. The Primary Study Area is located on bedrock of the Great Valley Sequence (western portion) and recent alluvial deposits (eastern portion). Focal depths are generally deeper than 15 miles (William Lettis & Associates, 2002). Historically, the Primary Study Area has a low seismic activity rate. Data from the Northern California Seismic Network database indicate that no seismic event greater than M4.5 has occurred since 1970. Sparse data from the historical seismic record show nothing greater than a M4.5 (William Lettis & Associates, 2002).

17.2.4.4 Seismic-Related Ground Failure including Liquefaction

Liquefaction is the sudden temporary loss of shear strength in saturated loose to medium dense granular sediments subjected to ground shaking. Liquefaction generally occurs when seismically induced ground shaking causes pore water pressure to increase to a point equal to the weight of the overlying soil and rock above the water table. Liquefaction can cause foundation failure of buildings and other facilities due to the reduction of foundation bearing strength. The potential for liquefaction depends on the duration and intensity of earthquake shaking, particle size distribution of the soil, density of the soil, and elevation of the groundwater. Areas at risk due to the effects of liquefaction are typified by a high groundwater table and underlying loose to medium-dense granular sediments, particularly younger alluvium and artificial fill.

Liquefaction potential is low in the western portion of the Primary Study Area because the soils are well-drained (i.e., low groundwater table) and decreased depth to bedrock. Liquefaction potential in the eastern portion is moderate due to the higher groundwater table and greater soil depth. Project features located in this area include the Hothouse Reservoir Complex, the TRR and its associated facilities, the Delevan Pipeline, the Delevan Pipeline Intake/Discharge Facilities, and the Delevan Transmission Line

17.2.4.5 Landslides

Slope failures, commonly referred to as landslides, include many phenomena that involve the downslope displacement and movement of material, either triggered by static (i.e., gravity) or dynamic (i.e., earthquake) forces. Rock slopes exposed to either air or water can undergo rockfalls, rockslides, or rock avalanches; soil slopes experience shallow soil slides, rapid debris flows, and/or deep-seated rotational slides.

Landslide potential is low in the eastern portion of the Primary Study Area where the land profile is relatively flat. Landslide potential increases in the western upland portion where steeper slopes occur. Small to medium landslides have been observed on steep slopes within and adjacent to the proposed Sites Reservoir, particularly along the western side of Logan Ridge (eastern shoreline of proposed Sites Reservoir). These landslides occur in the Boxer Formation, which is composed primarily of mudstone. Small isolated rockslides have been observed within and adjacent to the proposed Sites and Golden Gate damsites. These rockslides occur in the Venado Sandstone member of the Cortina Formation.

17.2.4.6 Seiches and Tsunamis

The Primary Study Area is not located downslope of any large bodies of water, nor is it located within a coastal area. Therefore, existing hazards due to earthquake-induced seiches (wave oscillations in an enclosed or semi-enclosed body of water) or tsunamis (seismic sea waves) are negligible. The existing Funks Reservoir is considered too small to produce a significant seiche.

17.2.4.7 Reservoir-Induced Seismicity

The only existing reservoir within the Primary Study Area is Funks Reservoir. Depth of the water in the reservoir is the most important factor in reservoir-induced seismicity (Probe International, 2008). Funks Reservoir is too shallow to create reservoir-induced seismicity.

17.3 Environmental Impacts/Environmental Consequences

17.3.1 Regulatory Setting

Seismic hazards, as related to the building of structures, are regulated at the federal, State, and local levels. Provided below is a list of the applicable regulations. These regulations are discussed in detail in Chapter 4 Environmental Compliance and Permit Summary of this EIR/EIS.

17.3.1.1 Federal Plans, Policies, and Regulations

- National Earthquake Hazards Reduction Program Reauthorization Act of 2004

17.3.1.2 State Plans, Policies, and Regulations

- California Water Code, Division 3 Dams and Reservoirs
- Seismic Hazards Mapping Act of 1990
- Alquist-Priolo Earthquake Fault Zoning Act of 1972
- California Division of Mines and Geology Special Publication No. 42, Fault-Rupture Hazard Zones in California, 2007
- California Division of Mines and Geology Special Publication No. 117A, Guidelines for Evaluating and Mitigating Seismic Hazards in California, 2008
- California Code of Regulations, Title 23 Waters, Division 2 Department of Water Resources, Chapter 1 Dams and Reservoirs, Article 5

17.3.1.3 Regional and Local Plans, Policies, and Regulations

- Colusa County General Plan
- Glenn County General Plan

17.3.2 Evaluation Criteria and Significance Thresholds

Significance criteria represent the thresholds that were used to identify whether an impact would be significant. Appendix G of the *CEQA Guidelines* suggests the following evaluation criteria for faults and seismicity:

Would the Project:

- Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:
 - Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault?
 - Strong seismic ground shaking?
 - Seismic-related ground failure, including liquefaction?
 - Landslides?
- Inundation by seiche, tsunami, or mudflow?

The evaluation criteria used for this impact analysis represent a combination of the Appendix G criteria and professional judgment that considers current regulations, standards, and/or consultation with agencies, knowledge of the area, and the context and intensity of the environmental effects, as required pursuant to NEPA. For the purposes of this analysis, an alternative would result in a significant impact if it would result in any of the following:

- Exposure of people or structures to fault rupture, seismic ground shaking, seismic-related ground failure, liquefaction, or landslides.
- Inundation by seiches or tsunamis.
- Reservoir-induced seismicity (increased seismicity due to the presence of a new reservoir or re-operation of existing reservoirs).

17.3.3 Impact Assessment Assumptions and Methodology

17.3.3.1 Assumptions

The following assumptions were made regarding Project-related construction, operation, and maintenance impacts to existing seismic hazards and impacts to the Project from those seismic hazards:

- Direct Project-related construction, operation, and maintenance activities would occur in the Primary Study Area.
- Direct Project-related operational effects would occur in the Secondary Study Area.
- The only direct Project-related construction activity that would occur in the Secondary Study Area is the installation of an additional pump into an existing bay at the Red Bluff Pumping Plant.
- The only direct Project-related maintenance activity that would occur in the Secondary Study Area is the sediment removal and disposal at the two intake locations (i.e., GCID Canal Intake and Red Bluff Pumping Plant).
- No direct Project-related construction or maintenance activities would occur in the Extended Study Area.
- Direct Project-related operational effects that would occur in the Extended Study Area are related to San Luis Reservoir operation; increased reliability of water supply to agricultural, municipal, and

industrial water users; and the provision of an alternate Level 4 wildlife refuge water supply. Indirect effects to the operation of certain facilities that are located in the Extended Study Area, and indirect effects to the consequent water deliveries made by those facilities, would occur as a result of implementing the alternatives.

- The existing bank protection located upstream of the proposed Delevan Pipeline Intake/Discharge facilities would continue to be maintained and remain functional.
- No additional channel stabilization, grade control measures, or dredging in the Sacramento River at or upstream of the Delevan Pipeline Intake or Discharge Facilities would be required.
- Likely sources of major regional seismicity would be from earthquakes to the west of the Project area in the Coast Range or from a very rare Cascadia Subduction Zone event (occurrence every 500 to 600 years).
- No undiscovered major faults or seismic sources would have an impact.

17.3.3.2 Methodology

A combination of data, published reports, and professional experience with initial investigations for the proposed Project was used to evaluate the alternatives for potential impacts due to faults and seismicity.

The Extended and Secondary study area impact assessments primarily relied on data and publications (both printed and web-based) from the California Geological Survey and the United States Geological Survey. The Primary Study Area impact assessments primarily relied on the Phase II Fault and Seismic Hazards Investigation for the NODOS Integrated Storage Investigations (William Lettis & Associates, Inc., 2002). Professional experience with initial investigations included geological mapping within the Primary Study Area and core-drilling within the footprints of the proposed damsites.

17.3.4 Topics Eliminated from Further Analytical Consideration

No Project facilities or topics that are included in the significance criteria listed above were eliminated from further consideration in this chapter.

17.3.5 Impacts Associated with the No Project/No Action Alternative

17.3.5.1 Extended and Secondary Study Areas – No Project/No Action Alternative

Construction, Operation, and Maintenance Impacts

Agricultural Water Use, Municipal and Industrial Water Use, Wildlife Refuge Water Use, San Luis Reservoir, Trinity Lake, Lewiston Lake, Trinity River, Klamath River downstream of the Trinity River, Whiskeytown Lake, Spring Creek, Shasta Lake, Keswick Reservoir, Sacramento River, Clear Creek, Lake Oroville, Thermalito Complex, Feather River, Sutter Bypass, Yolo Bypass, Folsom Lake, Lake Natoma, American River, Sacramento-San Joaquin Delta, Suisun Bay, San Pablo Bay, and San Francisco Bay

Impact Seis-1: Exposure of People or Structures to Fault Rupture, Seismic Ground Shaking, Seismic-Related Ground Failure, Liquefaction, or Landslides

The No Project/No Action Alternative includes implementation of projects and programs being constructed, or those that have gained approval, as of June 2009. The impacts of these projects have

already been evaluated on a project-by-project basis, pursuant to CEQA and/or NEPA, and their potential for impacts to or from seismic hazards has been addressed in those environmental documents. In addition, the Project would not be constructed if this alternative is implemented. Therefore, **there would not be a substantial adverse effect**, when compared to Existing Conditions.

Population growth will continue to occur throughout California throughout the period of Project analysis (i.e., 100 years), is included in the assumptions for the No Project/No Action Alternative, and as such, it may be expected to occur throughout the Extended and Secondary study areas. Growth within the counties is planned and guided in the various county General Plans, and structures that are constructed to accommodate such growth are expected to be constructed in suitable areas to applicable and appropriate seismic standards. In addition, the growth-inducing effects of the projects that are included in the No Project/No Action Alternative, as well as from planned growth in the counties that comprise the two study areas, are expected to have been addressed in the environmental documents that addressed those projects and County General Plans, pursuant to CEQA and/or NEPA. Therefore, growth would not affect these seismic hazards, and the seismic hazards are not expected to affect growth within the Extended or Secondary Study Area counties. Consequently, **there would not be a substantial adverse effect**, when compared to Existing Conditions. San Luis Reservoir, Shasta Lake, Lake Oroville, and Folsom Lake operations do not currently cause seismic hazards, and their continued operation is not expected to change that condition. Therefore, **there would not be a substantial adverse effect**, when compared to Existing Conditions.

Impact Seis-2: Inundation by Seiches or Tsunamis

The impacts of the projects that are included in the No Project/No Action Alternative have been evaluated on a project-by-project basis, pursuant to CEQA and/or NEPA. Their potential for impacts to or from seiches or tsunamis has been addressed in those environmental documents. In addition, the Project would not be constructed if this alternative is implemented. Population growth may be expected to occur throughout the Extended and Secondary study areas. The growth-inducing effects of the projects that are included in the No Project/No Action Alternative, as well as from planned growth in the counties that comprise the two study areas, are also expected to have been addressed in the environmental documents that addressed those projects and County General Plans, pursuant to CEQA and/or NEPA. Therefore, **there would not be a substantial adverse effect**, when compared to Existing Conditions. In addition, San Luis Reservoir, Shasta Lake, Lake Oroville, and Folsom Lake are not located on the coast, so they are not expected to cause or be affected by seiches or tsunamis. Therefore, **there would not be a substantial adverse effect**, when compared to Existing Conditions.

Impact Seis-3: Reservoir-Induced Seismicity

The impacts of the projects that are included in the No Project/No Action Alternative have been evaluated on a project-by-project basis, pursuant to CEQA and/or NEPA. Their potential for impacts to or from reservoir-induced seismicity has been addressed in those environmental documents. In addition, the Project would not be constructed if this alternative is implemented. Therefore, **there would not be a substantial adverse effect**, when compared to Existing Conditions.

The only examples of suspected reservoir-induced seismicity associated with existing State and federal reservoirs located within the Extended and Secondary study areas occurred over 35 years ago (San Luis Reservoir in 1969 and Lake Oroville in 1975). Major State and federal reservoirs within the Extended and Secondary study areas (Shasta, Folsom, San Luis, and Oroville) have been operated according to

established engineering guidelines since their completion in 1945 (Shasta), 1956 (Folsom), 1967 (San Luis), and 1968 (Oroville) and will continue to operate according to these same guidelines in the future. The continued absence of reservoir-induced seismicity that has characterized the past 35 to 70 years of operation of these very large reservoirs should be anticipated in the future. Therefore, **there would not be a substantial adverse effect**, when compared to Existing Conditions.

Modifications to operations of existing reservoirs would also have been evaluated pursuant to CEQA and/or NEPA, and any potentially significant or significant impact that was identified would have been addressed in those environmental documents. Therefore, **there would not be a substantial adverse effect**, when compared to Existing Conditions.

17.3.5.2 Primary Study Area – No Project/No Action Alternative

Construction, Operation, and Maintenance Impacts

Impact Seis-1: Exposure of People or Structures to Fault Rupture, Seismic Ground Shaking, Seismic-Related Ground Failure, Liquefaction, or Landslides

If the No Project/No Action Alternative is implemented, Sites Reservoir and its associated facilities would not be constructed. Therefore, Project-induced seismic impacts (including fault rupture, strong seismic ground shaking, and seismic-related ground failure) and liquefaction and landslides would be avoided in the Primary Study Area, and **would not have a substantial adverse effect**, when compared to Existing Conditions.

It is acknowledged that population growth may occur within Glenn and Colusa counties. Growth within the counties is planned and guided in the two counties' General Plans, and structures that are constructed to accommodate such growth are expected to be constructed in suitable areas to applicable and appropriate seismic standards. Therefore, growth would not affect these seismic phenomena, and the phenomena are not expected to affect growth within the counties. Consequently, **there would not be a substantial adverse effect**, when compared to Existing Conditions.

Impact Seis-2: Inundation by Seiches or Tsunamis

If the No Project/No Action Alternative is implemented, the Project would not be completed. Therefore, there would be no increase in the risk of inundation by seiches or tsunamis to people or structures in the Primary Study Area from Project facilities. Therefore, **there would not be a substantial adverse effect**, when compared to Existing Conditions. Population growth may occur within Glenn and Colusa counties. Neither county is located on the coast; therefore, a seiche or tsunami would not occur there, **and would not have a substantial adverse effect** on additional people who may move into those counties in the future, when compared to Existing Conditions.

Impact Seis-3: Reservoir-Induced Seismicity

If the No Project/No Action Alternative is implemented, the Project would not be completed. Therefore, there would be no increase in the risk of reservoir-induced seismicity in the Primary Study Area. Projects and programs that are included in the No Project/No Action Alternative are not located within Glenn or Colusa counties, so they would not cause reservoir-induced seismicity in those counties. In addition, population growth and associated urban/suburban/rural development that may occur within the two counties in the future is expected to not affect reservoirs located within the counties. Therefore, **there would not be a substantial adverse effect**, when compared to Existing Conditions.

17.3.6 Impacts Associated with Alternative A

17.3.6.1 Extended and Secondary Study Areas – Alternative A

Construction, Operation, and Maintenance Impacts

Agricultural Water Use, Municipal and Industrial Water Use, Wildlife Refuge Water Use, San Luis Reservoir, Pump Installation at the Red Bluff Pumping Plant, Trinity Lake, Lewiston Lake, Trinity River, Klamath River downstream of the Trinity River, Whiskeytown Lake, Spring Creek, Shasta Lake, Keswick Reservoir, Sacramento River, Clear Creek, Lake Oroville, Thermalito Complex, Feather River, Sutter Bypass, Yolo Bypass, Folsom Lake, Lake Natoma, American River, Sacramento-San Joaquin Delta, Suisun Bay, San Pablo Bay, and San Francisco Bay

Impact Seis-1: Exposure of People or Structures to Fault Rupture, Seismic Ground Shaking, Seismic-Related Ground Failure, Liquefaction, or Landslides

With the exception of installing an additional pump at the RBPP, no Project facilities would be constructed, operated, or maintained in the Extended or Secondary study areas. When compared to Existing Conditions and the No Project/No Action Alternative, Project facilities would not expose people or structures to fault rupture, seismic ground shaking, seismic-related ground failure, liquefaction, or landslides. Similarly, those seismic events, if they occurred, would not affect Project facilities because most facilities would not be developed within those areas. The installation of a pump within the existing RBPP would not affect and is not expected to be affected by seismic events. There would be **no impact**, when compared to Existing Conditions and the No Project/No Action Alternative. In addition, the continued operation of San Luis Reservoir, Shasta Lake, Lake Oroville, and Folsom Lake would not cause these seismic events, resulting in **no impact**, when compared to Existing Conditions and the No Project/No Action Alternative.

Impact Seis-2: Inundation by Seiches or Tsunamis

Because no Project facilities would be constructed, operated, or maintained in the Extended or Secondary study areas (other than one pump to be installed at the existing RBPP), Project facilities would not be affected by seiches or tsunamis, if they were to occur there, resulting in **no impact**, when compared to Existing Conditions and the No Project/No Action Alternative. The installation of a pump within the existing RBPP would not affect and is not expected to be affected by a tsunami because the RBPP is not located in a coastal area, and it would not be affected by a seiche because it is not located on a waterbody. The continued operation of San Luis Reservoir would have **no impact**, when compared to Existing Conditions and the No Project/No Action Alternative, on tsunamis because the reservoir is not located in a coastal area. During the continued operation of San Luis Reservoir, Shasta Lake, Lake Oroville, and Folsom Lake, it is possible that a large earthquake-induced landslide could cause a seiche on these reservoirs. However, the seiche would be small to moderate, resulting in a **less-than-significant impact** when compared to Existing Conditions or the No Project/No Action Alternative.

Impact Seis-3: Reservoir-Induced Seismicity

The only examples of suspected reservoir-induced seismicity associated with existing State and federal reservoirs located within the Extended and Secondary Study Areas occurred over 35 years ago (San Luis Reservoir, 1969 and Lake Oroville, 1975). Major State and federal reservoirs within the Extended and Secondary study areas (Shasta, Folsom, San Luis and Oroville) have been operated according to established engineering guidelines since their completion in 1945 (Shasta), 1956 (Folsom),

1967 (San Luis) and 1968 (Oroville) and will continue to operate according to these same guidelines in the future. The continued absence of reservoir-induced seismicity that has characterized the past 35 to 70 years of operation of these very large reservoirs should be anticipated in the future resulting in **no impact**, when compared to Existing Conditions and the No Project/No Action Alternative. In addition, the addition of one pump to an existing bay at the RBPP would not cause or be affected by reservoir-induced seismicity because the RBPP is not located near or on a reservoir, resulting in **no impact**, when compared to Existing Conditions and the No Project/No Action Alternative.

17.3.6.2 Primary Study Area – Alternative A

Construction, Operation, and Maintenance Impacts

All Primary Study Area Project Facilities

Impact Seis-1: Exposure of People or Structures to Fault Rupture, Seismic Ground Shaking, Seismic-Related Ground Failure, Liquefaction, or Landslides

There are very few seismic hazard areas within the Primary Study Area. No active faults are known to be present within or immediately adjacent to the Primary Study Area, and there is low risk of fault failure (CGS, 2003a). Because there are few active faults in proximity to the Primary Study Area, the likelihood of fault rupture, strong seismic ground shaking and seismic-related liquefaction or landslides is also low. Detailed site-specific geologic and foundation investigations were used to develop design criteria to withstand reasonably probable seismic events.

The Phase II Fault and Seismic Hazards Investigation for the NODOS Integrated Storage Investigations (William Lettis & Associates, Inc., 2002) concluded that a three- to eight-inch fault slippage could occur along the northeast-striking GG-1, GG-2, GG-3, and S-2 faults that are located beneath the Project damsites or in proximity to them. DSOD would require that the design specifications be sufficient to mitigate an impact related to this slippage. Therefore, constructing, operating, and maintaining the Project facilities in this area would result in a **less-than-significant impact**, when compared to Existing Conditions and the No Project/No Action Alternative.

Project construction would involve creating high-angle temporary slopes at damsites, quarry areas, new roads, recreation areas, and temporary and permanent access roads. Project construction would also include trenching along the Delevan Pipeline. Localized slumping (i.e., landslides or trench wall failure) and liquefaction due to seismic shaking would pose a moderate threat, resulting in a **potentially significant impact**, when compared to Existing Conditions and the No Project/No Action Alternative.

During Project operation, increased soil moisture and reservoir surface level fluctuations along the shores of Sites Reservoir could exacerbate slope instability (particularly along the eastern shoreline west of Logan Ridge) and increase earthquake-induced landslide potential. Therefore, operation of the Project in this area would result in a **potentially significant impact**, when compared to Existing Conditions and the No Project/No Action Alternative.

Impact Seis-2: Inundation by Seiches or Tsunamis

The Primary Study Area is not located in a coastal area. Therefore, significant hazards due to earthquake-tsunamis (seismic sea waves) are negligible. It is possible that a large earthquake-induced landslide could cause a seiche on Sites Reservoir, but the seiche would be small to moderate and would result in a

less-than-significant impact, when compared to Existing Conditions and the No Project/No Action Alternative.

Impact Seis-3: Reservoir-Induced Seismicity

Alternative A proposes a 1.27-MAF Sites Reservoir, with a maximum depth of approximately 220 feet. Reservoirs are classified as deep (80 meters, 263 feet) to very deep (deeper than 150 meters, 492 feet). Sites Reservoir would be classified as a less than deep reservoir. Deep and very deep reservoirs account for the majority of reported examples of reservoir-induced seismicity (USGS, 1996b). Therefore, potential effects from reservoir-induced seismicity caused by Sites Reservoir would result in a **less-than-significant impact**, when compared to Existing Conditions and the No Project/No Action Alternative.

The smaller Holthouse Reservoir and TRR would be too shallow to create reservoir-induced seismicity, and would, therefore, result in **no impact**, when compared to Existing Conditions and the No Project/No Action Alternative.

17.3.7 Impacts Associated with Alternative B

17.3.7.1 Extended and Secondary Study Areas – Alternative B

Construction, Operation, and Maintenance Impacts

The impacts associated with Alternative B, as they relate to seismic conditions (**Impact Seis-1**), seiches or tsunamis (**Impact Seis-2**), and reservoir-induced seismicity (**Impact Seis-3**), would be the same as described for Alternative A for the Extended and Secondary study areas.

17.3.7.2 Primary Study Area – Alternative B

Construction, Operation, and Maintenance Impacts

The impacts associated with Alternative B, as they relate to seismic conditions (**Impact Seis-1**) and seiches or tsunamis (**Impact Seis-2**), would be the same as described for Alternative A for all Primary Study Area Project facilities.

The impacts associated with Alternative B, as they relate to reservoir-induced seismicity (**Impact Seis-3**), would be the same as described for Alternative A for all Primary Study Area Project facilities, with the exception of Sites Reservoir. Alternative B includes a 1.81-MAF Sites Reservoir, compared to the 1.27-MAF Sites Reservoir evaluated for Alternative A. The potential impacts of the larger reservoir on reservoir-induced seismicity are discussed below.

Sites Reservoir Inundation Area

Impact Seis-3: Reservoir-Induced Seismicity

The Alternative B 1.81-MAF Sites Reservoir would have a maximum depth of approximately 260 feet, which is on the threshold of classifying it as a deep reservoir. However, the Alternative B Sites Reservoir would still be classified as a less than deep reservoir. Deep and very deep reservoirs account for the majority of reported examples of reservoir-induced seismicity (USGS, 1996b). Therefore, potential effects from reservoir-induced seismicity would result in a **less-than-significant impact**, when compared to Existing Conditions and the No Project/No Action Alternative.

17.3.8 Impacts Associated with Alternative C

17.3.8.1 Extended and Secondary Study Areas – Alternative C

Construction, Operation, and Maintenance Impacts

The impacts associated with Alternative C, as they relate to seismic conditions (**Impact Seis-1**), seiches or tsunamis (**Impact Seis-2**), and reservoir-induced seismicity (**Impact Seis-3**), would be the same as described for Alternative A for the Extended and Secondary study areas.

17.3.8.2 Primary Study Area – Alternative C

Construction, Operation, and Maintenance Impacts

The impacts associated with Alternative C, as they relate to seismic conditions (**Impact Seis-1**) and seiches or tsunamis (**Impact Seis-2**), would be the same as described for Alternative A for all Primary Study Area Project facilities.

The impacts associated with Alternative C, as they relate to reservoir-induced seismicity (**Impact Seis-3**), would be the same as described for Alternative A for all Primary Study Area Project facilities, with the exception of Sites Reservoir. Alternatives B and C include a 1.81-MAF Sites Reservoir. Therefore, the impacts associated with the Alternative C Sites Reservoir, as related to reservoir-induced seismicity (**Impact Seis-3**), would be the same as described for Alternative B for Sites Reservoir.

17.4 Mitigation Measures

Mitigation measures are provided below and summarized in Table 17-5 for the impacts that have been identified as significant or potentially significant.

**Table 17-5
Summary of Mitigation Measures for
NODOS Project Impacts to/from Faults and Seismicity**

Impact	Associated Project Facility	LOS Before Mitigation	Mitigation Measure	LOS After Mitigation
Impact Seis-1: Exposure of People or Structures to Fault Rupture, Seismic Ground Shaking, Seismic-Related Ground Failure, Liquefaction, or Landslides	Road Relocations, Recreation Areas, Delevan Pipeline, Quarry Areas, All Project Damsites	Potentially Significant	Mitigation Measure Seis-1: Implement Slope Stabilization Methods; Design Facilities to Withstand Fault Rupture, Seismic Ground Shaking, and Ground Failure, and Liquefaction	Less than Significant

Note:

LOS = Level of Significance

To mitigate **Impact Seis-1**, implement **Mitigation Measure Seis-1**, as follows:

Mitigation Measure Seis-1: Implement Slope Stabilization Methods; Design Facilities to Withstand Fault Rupture, Seismic Ground Shaking, and Ground Failure, and Liquefaction

- The two main Project dams would be located on a fault. To minimize potential seismic-related Project impacts, the Project design includes features such as wide clay cores and additional filter material to reduce the risk of dam failure. In addition, temporary and permanent excavation cut slopes shall be designed to be stable. If slope instability is detected, excavation cut slopes shall be stabilized by flattening, installing engineered retaining structures, and/or providing appropriate drainage elements. Shoring shall be used to support vertical trench walls. Re-sloping or removal is the most common method of landslide or slope stabilization. Structural solutions are as listed. The proposed dams, dikes, and powerplants shall be designed to survive fault rupture, seismic ground shaking and ground failure, and liquefaction without loss of the reservoir or catastrophic damage. These hazards are of far less concern during construction when there is no potential for an uncontrolled reservoir release. Additionally, the probability of these hazards occurring during the relatively short Project construction period is remote, and steps to mitigate for them are not typically included in the design of a temporary structure. Construction mitigation would normally include excavating stable cutslopes and locating staging areas away from steep slopes or areas of suspected liquefiable soils or ground rupture. Dewatering may be required for temporary excavation cutslopes and shored or un-shored trenches (CGS, 2008b). During Project operation, landslide mitigation shall include adding earth or rock buttresses at the toes of potential slope failures following best management practices (BMPs) (USGS, 2000). Additionally, restraining walls, piles, caissons, rock anchors, or geotextiles shall be used to prevent or control slope movement.

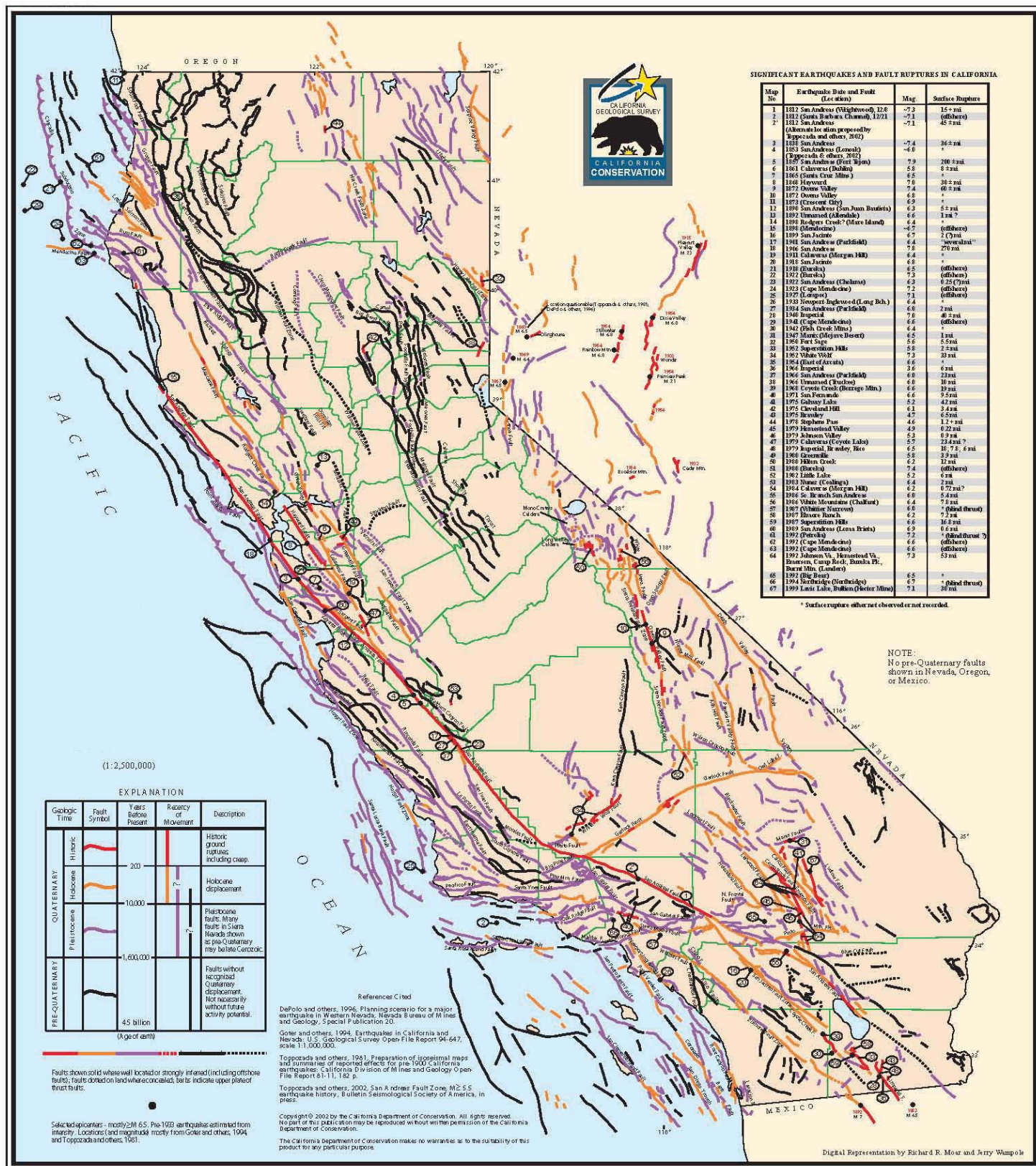
Implementation of **Mitigation Measure Seis-1** would reduce the level of significance of Project impacts to/from faults and seismicity to **less than significant**.

17.5 References

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Figures



Compiled by Charles W. Jennings and George J. Saucedo
1999 (Revised 2002, Toussou Toppe and David Branum)

FIGURE 17-1
Simplified Fault Activity in California
North-of-the Delta Offstream Storage Project

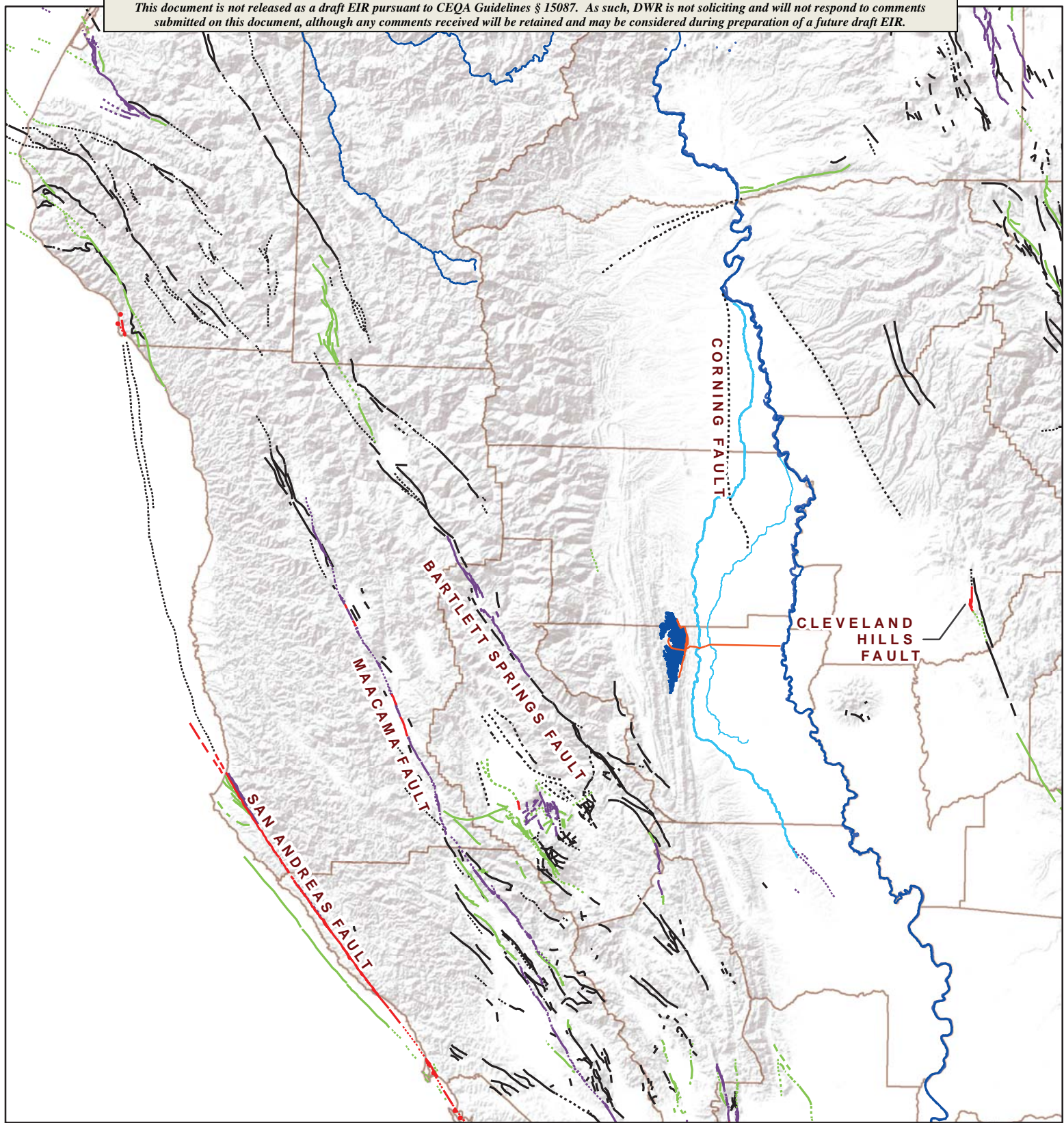


FIGURE 17-2
Regional Faults

North-of-the-Delta Offstream Storage Project

Legend

Quaternary Faults

- Historic Displacement (Last 200 Years)
- Holocene Displacement (Last 11,000 Years)
- Late Quarternary Displacement (Last 750,000 years)
- Undivided Quarternary Displacement (Last 1,600,000 Years)

— Delevan Transmission Line

— Rivers

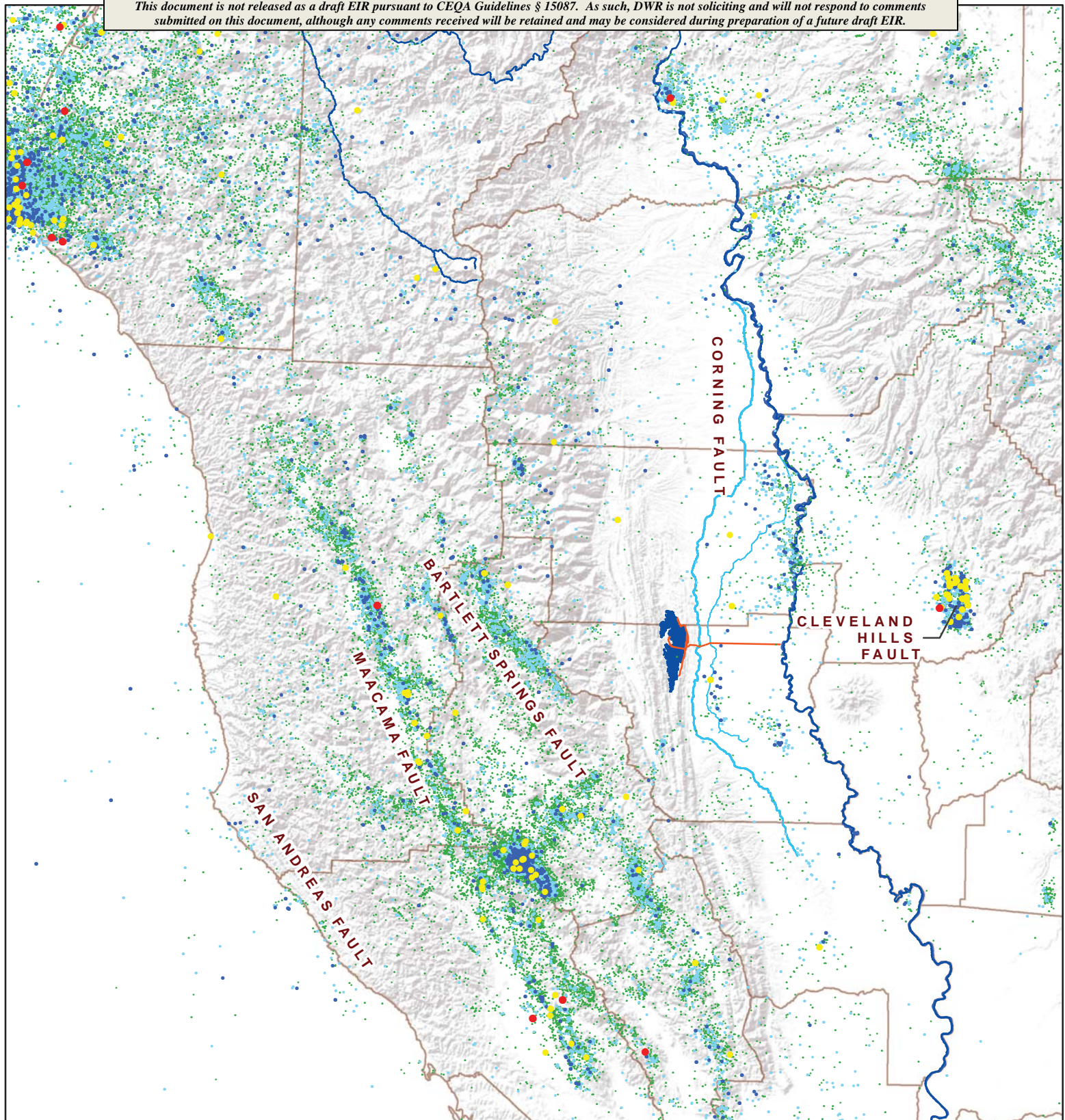
— Canal

— Proposed Sites Reservoir

— County Boundary

0 5 10 20 30 40 50
Miles





Legend

Earthquake Epicenters

- Magnitude
- 1 - 2
 - 2 - 3
 - 3 - 4
 - 4 - 5
 - 5 - 6

- Delevan Transmission Line
- Rivers
- Canal
- Proposed Sites Reservoir
- County Boundary

FIGURE 17-3

Regional Seismicity

North-of-the-Delta Offstream Storage Project

0 5 10 20 30 40 50 Miles



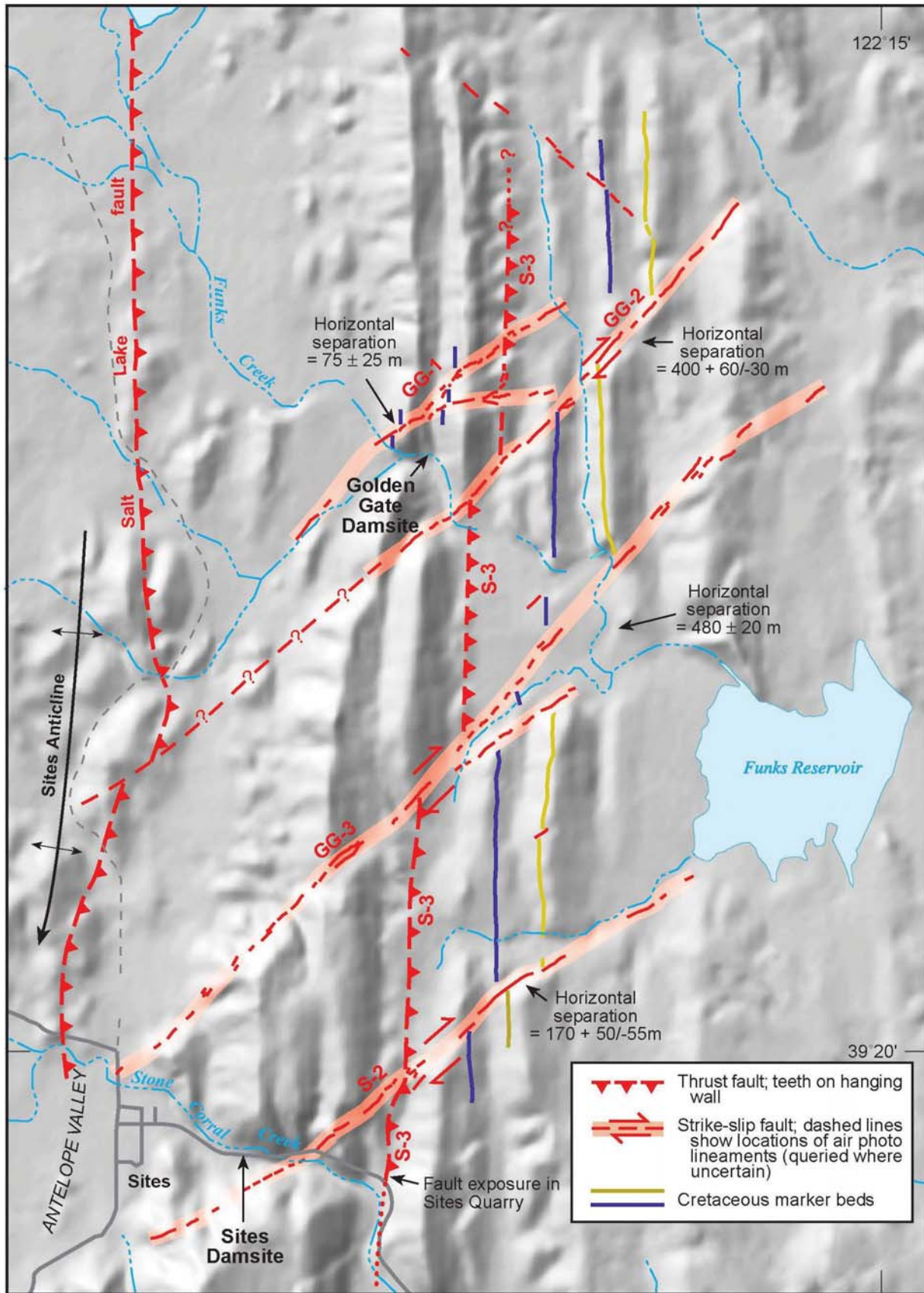


FIGURE 17-4
Faults in the Vicinity of Project Damsites
 North-of-the Delta Offstream Storage Project